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AP - JP19980376569 19981224

IN - YUKI TSUTOMU

PA - RICOH CO LTD

TI - AUTOMATIC ORDERING SYSTEM

AB - PROBLEM TO BE SOLVED: To automatically order consumption articles, of which the supply is requested, from the information of consumption articles of OA equipment connected to a network and the stock information of respective consumption articles.

- SOLUTION: This stock of consumption articles of OA equipment is managed and the consumption articles to be lacked automatically order to the ordering destination 5 by automatic ordering terminal equipment 1 connected with printers 3a and 3b and copy machines 4a and 4b through networks 2a and 2b. The automatic ordering terminal equipment 1 is provided with a stock information managing means, OA equipment managing means for acquiring the information on consumption articles of OA equipment through the networks, supply amount calculating means for calculating the supply amount of consumption articles from the information, lack detecting means and ordering means, the consumption articles to be lacked are detected based on the stock amount and supply amount by fine lack detecting means and the consumption articles are ordered through a facsimile or mail to the ordering destination 5 by the ordering means.

I - G06F17/60 ;B41J29/38 ;G03G21/00 ;H04N1/00

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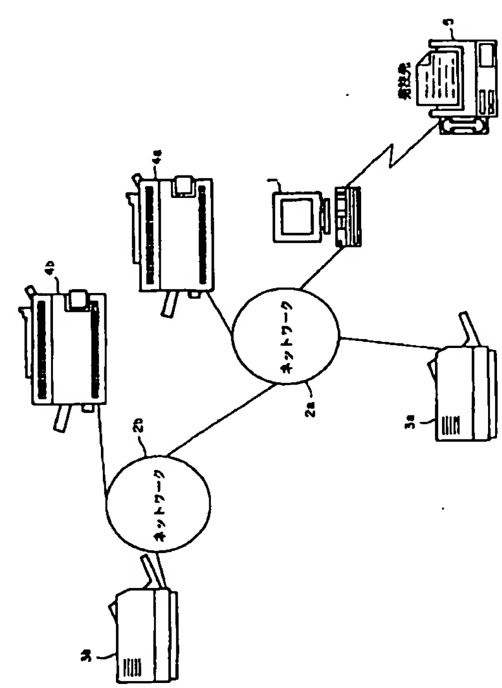
(54)【発明の名称】　自動発注システム

(57)【要約】
【課題】　ネットワークに接続されているＯＡ機器の消耗品の情報及び各消耗品の在庫情報から供給が要求される消耗品を自動的に発注する。
【解決手段】　プリンタ３ａ，３ｂ、複写機４ａ，４ｂとネットワーク２ａ，２ｂによって接続されている自動発注端末装置１により、ＯＡ機器の消耗品の在庫を管理し、不足しそうな消耗品を発注先５に自動的に発注する。自動発注端末装置１は、在庫情報管理手段と、ネットワークを介してＯＡ機器の消耗品の情報を取得するためのＯＡ機器管理手段と、情報より消耗品の供給量を計算する供給量計算手段と、欠品検出手段及び発注手段とを備え、欠品検出手段によって在庫量と供給量に基づいて不足になりそうな消耗品を検出し、発注手段によって発注元５にファクシミリやメール等で消耗品の発注を行う。



【特許請求の範囲】

【請求項１】　ネットワークに接続されているオフィス・オートメーション機器及び自動発注端末装置からなる自動発注システムにおいて、前記自動発注端末装置は、前記オフィス・オートメーション機器の消耗品の在庫を管理する在庫情報管理手段と、前記ネットワークを介して前記オフィス・オートメーション機器の前記消耗品の情報を取得するためのオフィス・オートメーション機器管理手段と、前記情報より前記消耗品の供給量を計算する供給量計算手段と、前記在庫の量と前記供給量に基づいて不足になりそうな前記消耗品を検出するための欠品検出手段と、前記消耗品の発注を行う発注手段とを備えていることを特徴とする自動発注システム。

【請求項２】　請求項１に記載の自動発注システムにおいて、前記オフィス・オートメーション機器管理手段は、前記オフィス・オートメーション機器の消耗品供給装置に異常があった場合は、前記ネットワークを介して前記オフィス・オートメーション機器がもつ処理履歴等の総計情報を取得することを特徴とする自動発注システム。

【請求項３】　ネットワークに接続されているオフィス・オートメーション機器及び自動発注端末装置からなる自動発注システムにおいて、前記自動発注端末装置は、前記オフィス・オートメーション機器の消耗品の在庫を管理する在庫情報管理手段と、前記ネットワークを介して前記オフィス・オートメーション機器の前記消耗品の情報及び処理履歴等の総計情報を取得し記憶装置に記憶して管理するためのオフィス・オートメーション機器管理手段と、前記記憶装置に記憶された前記消耗品の情報及び総計情報より前記消耗品の供給量を予測的に計算する供給量計算手段と、前記在庫の量と前記供給量に基づいて不足になりそうな前記消耗品を検出するための欠品検出手段と、前記消耗品の発注を行う発注手段とを備えていることを特徴とする自動発注システム。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、自動発注システム、より詳細には、ネットワークに接続したオフィス・オートメーション機器（以下、ＯＡ機器）がもつ各消耗品の情報及び履歴等の総計情報を取得し、欠品が出そうな消耗品をファクシミリ等で自動的に発注する自動発注システムに関する。

【０００２】

【従来の技術】プリンタ装置及び複写機などのＯＡ機器では、記録紙やトナー等の消耗品がなくなる前に供給要求が必要と判断された場合は、パネル等にて消耗品の供給を要求する。ユーザーは、在庫から必要な消耗品を取り出し、ＯＡ機器にその消耗品の供給を行う。もし、記録紙やトナー等の消耗品がなくなった場合は、電話等で納入業者に消耗品の発注を行う。また、特開平８－３１５０５２号公報には、消耗品がなくなったときに自動的に発注を行うシステムが記載されている。

【０００３】

【発明が解決しようとする課題】しかしながら、消耗品の発注中は、ＯＡ機器が消耗品の供給が要求されても、消耗品の供給ができずに、印刷あるいはコピー作業ができなくなる。更に、各プリンタ装置及び複写機には、各消耗品の情報を取得できるが、記録紙やトナー等の供給装置の故障のため正確に各消耗品の情報を取得できない場合や、ハードのトラブルにより各消耗品の残量及び印刷結果，履歴等の総計情報が取れない場合がある。

【０００４】本発明は上述のごとき実情に鑑みてなされたものであり、ネットワークに接続されているＯＡ機器の消耗品の情報及び各消耗品の在庫情報から供給が要求される消耗品を自動的に発注する自動発注システムを提供すること、更にＯＡ機器の供給装置の故障により正確に各消耗品の情報を取得できない場合やＯＡ機器のハードのトラブルにより各消耗品の残量及び印刷結果の総計情報が取れない場合においても供給が要求される消耗品を自動的に発注する自動発注システムを提供することを目的とする。

【０００５】

【課題を解決するための手段】請求項１の発明は、ネットワークに接続されているオフィス・オートメーション機器及び自動発注端末装置からなる自動発注システムにおいて、前記自動発注端末装置は、前記オフィス・オートメーション機器の消耗品の在庫を管理する在庫情報管理手段と、前記ネットワークを介して前記オフィス・オートメーション機器の前記消耗品の情報を取得するためのオフィス・オートメーション機器管理手段と、前記情報より前記消耗品の供給量を計算する供給量計算手段と、前記在庫の量と前記供給量に基づいて不足になりそうな前記消耗品を検出するための欠品検出手段と、前記消耗品の発注を行う発注手段とを備えていることを特徴としたものである。

【０００６】すなわち、各消耗品の在庫情報（例えば、記録紙の枚数、トナーの個数など）を覚えておき、ＯＡ機器からの各消耗品の情報を参考にして消耗品の供給量を計算し、不足しそうな消耗品があれば、自動的にファクシミリやメール等で納入業者に発注を行う。

【０００７】請求項２の発明は、請求項１の発明において、前記オフィス・オートメーション機器管理手段は、前記オフィス・オートメーション機器の消耗品供給装置に異常があった場合は、前記ネットワークを介して前記オフィス・オートメーション機器がもつ処理履歴等の総計情報を取得することを特徴としたものである。

【０００８】すなわち、正確に各消耗品の情報を取得できない場合においては、印刷結果（履歴）の総計情報に記録されている出力枚数のカウンターより、各消耗品の必要な供給量を計算する。そこで、現在の各消耗品の在

庫情報（例えば、記録紙の枚数、トナーの個数など）とＯＡ機器が持つ各消耗品の情報及び印刷結果の総計情報を取得し、その情報から各消耗品の供給量を計算し、不足しそうな消耗品があれば、自動的にファクシミリやメール等で納入業者に発注を行う。

【０００９】請求項3の発明は、ネットワークに接続されているオフィス・オートメーション機器及び自動発注端末装置からなる自動発注システムにおいて、前記自動発注端末装置は、前記オフィス・オートメーション機器の消耗品の在庫を管理する在庫情報管理手段と、前記ネットワークを介して前記オフィス・オートメーション機器の前記消耗品の情報及び処理履歴等の総計情報を取得し記憶装置に記憶して管理するためのオフィス・オートメーション機器管理手段と、前記記憶装置に記憶された前記消耗品の情報及び総計情報より前記消耗品の供給量を予測的に計算する供給量計算手段と、前記在庫の量と前記供給量に基づいて不足になりそうな前記消耗品を検出するための欠品検出手段と、前記消耗品の発注を行う発注手段とを備えていることを特徴としたものである。

【００１０】すなわち、各消耗品の残量及び印刷結果の総計情報が取れない場合においては、過去の各消耗品の情報及び印刷結果（履歴）の総計情報を記憶しておき、過去の実績（例えば、最近１週間の平均出力枚数、各消耗品の平均残量など）を参考に、各消耗品の供給量を計算する。その供給量と在庫量から、不足しそうな消耗品があれば自動的にファクシミリやメール等で納入業者に発注を行う。

【００１１】

【発明の実施の形態】図1は、本発明における自動発注システムの構成例を示す図であり、図中、自動発注端末装置1は、ネットワーク２ａを介してプリンタ３ａ，複写機４ａと接続され、ネットワーク２ａは、ネットワーク２ｂを介してプリンタ３ｂ，複写機４ｂと接続される。また、自動発注端末装置１は、ファクシミリやメールを介して発注先５と接続される。

【００１２】図2は、本発明における自動発注システムを説明するためのブロック図であり、図２中、在庫情報管理手段１０は、各消耗品の在庫情報の入出力などの処理を行い、ＯＡ機器管理手段１１は、ネットワークに接続されているプリンタ及び複写機などのＯＡ機器の消耗品などの情報の取得や管理などの処理を行い、供給量計算手段１２は、各ＯＡ機器に必要な消耗品の供給量の計算を行い、欠品検出手段１３は、各消耗品の在庫量及び供給量を参考に、不足しそうな消耗品の検出を行う。また、発注手段１４は、発注先５に欠品検出手段１３において検出した消耗品の発注を行う。

【００１３】図3は、本発明の自動発注システムにおける第１の実施例を説明するためのフロー図、図4及び図5は、それぞれＯＡ機器の消耗品の在庫情報の構成及びそのデータの例を示す図、図6及び図7は、それぞれＯＡ機器の消耗品情報の構成及びそのデータの例を示す図であり、あらかじめ設定した自動発注時間に到達したとき（ステップＳ１）、自動発注端末装置１は以下の順で自動発注処理を行う。

【００１４】まず、在庫情報管理手段１０によって、在庫情報をロードする（ステップＳ２）。この在庫情報には、図4に示したサプライコード，サプライ名，在庫量，発注中の量を含み、例えば、図5に示すようにあらかじめ在庫にある各消耗品を自動発注端末装置１の入力装置を使って入力しておく。

【００１５】次に、ＯＡ機器管理手段１１によって、ネットワーク上に接続されている各ＯＡ機器の消耗品情報を、自動発注端末装置１のネットワークの入出力装置を使って取得する（ステップＳ３）。各ＯＡ機器の消耗品情報には、図6に示したサプライ名，最大供給量，残量を含み、例えば図7のような消耗品情報が取得できる。

【００１６】次に、供給量計算手段１２によって各消耗品の供給量を計算する（ステップＳ４）。実際には、各ＯＡ機器の消耗品情報を参考にし、記録紙のような消耗品の場合には、次式により必要な供給量を求める。トナーや感光体のような消耗品は、供給量を常に１個とする。

各消耗品の必要な供給量　＝　最大供給量　－　残量

例えば、図7におけるプリンタの消耗品情報から必要な供給量は、次のようになる。

記録紙Ａ４	：	１５００枚
記録紙Ａ３	：	２００枚
プリンタ用トナー	：	１個（あと５０％）
プリンタ用感光体	：	１個（１５０００枚印刷可能）

上述のごとくして求めた各ＯＡ機器の供給量から各消耗品ごとに全体の供給量（トータル）を計算する。

【００１７】次に、欠品検出手段１３によって、各消耗品の在庫量と供給量（トータル）を比較し（ステップＳ５）、供給量の方が多いときは、発注処理を行う。例えば、図5に示した在庫情報の場合、次のような在庫量となる。

記録紙Ａ４の在庫量	：	２５０００枚（在庫量＋発注中の量）
記録紙Ａ３の在庫量	：	２００００枚（在庫量＋発注中の量）

供給量（トータル）が次のような場合、発注対象は、記録紙Ａ４となる。

記録紙Ａ４の供給量	：	３００００枚（５０００枚不足）
記録紙Ａ３の供給量	：	１００００枚（１００００枚余裕）

【００１８】最後に、発注手段１４によって、発注対象となった消耗品と不足分の発注リストを作成し、ファクシミリやメール等で発注先に送信する（ステップＳ６）。例えば、記録紙Ａ４で５０００枚不足の場合、以

下のような発注リストになる。

サプライコード　：　０００１
サプライ名　　　：　記録紙Ａ４
発注量　　　　　：　５０００枚

【００１９】図8は、本発明の自動発注システムにおける第２の実施例を説明するためのフロー図、図９及び図１０は、それぞれ印刷結果を表す総計情報の構成及びそのデータの例を示す図であり、実施例２においては、実施例１におけるステップＳ３からステップＳ４の手順を以下のように変更する。

【００２０】ＯＡ機器管理手段１１によって、ネットワーク上に接続されている各ＯＡ機器の消耗品情報を、自動発注端末装置１のネットワークの入出力装置を使って取得する（ステップＳ１３）。ここで、消耗品情報の取得状況を判断し（ステップＳ１４）、供給装置の故障により各ＯＡ機器の消耗品情報の取得ができない場合には、総計情報を取得する（ステップＳ１５）。総計情報には、図９に示した印刷日付，ユーザー名，印刷名，出力用紙，出力枚数を含み、例えば、図１０のような総計情報が取得できる。

【００２１】次に、供給量計算手段１２によって、各消耗品の供給量を計算する（ステップＳ１６）。ステップＳ１４において消耗品情報が取得できた場合には、実施例１のステップＳ４と同様にして必要な供給量を求める。ステップＳ１４において消耗品情報が取得できなかった場合には、総計情報を取得し、（ステップＳ１５）各ＯＡ機器の総計情報を参考にし、各記録紙毎の出力枚数（トータル）を求める。対象となる日付は、前回の発注処理を行った日付から今回の発注処理の日付とする。例えば、図１０（Ａ）におけるプリンタ及び図１０（Ｂ）における複写機の出力枚数は、８月１日から８月２日までの日付を対象とすると、以下のようになる。

プリンタ　：　記録紙Ａ４が５０枚，記録紙Ａ３が５枚
複写機　　：　記録紙Ａ４が３５００枚，記録紙が２００枚

この出力枚数（トータル）を必要な供給量とする。また、トナーや感光体のような消耗品は、供給量を常に１個とする。

【００２２】図１１は、本発明の自動発注システムにおける第３の実施例を説明するためのフロー図であり、実施例３においては、実施例２におけるステップＳ１３からステップＳ１６の手順を以下のように変更する。

【００２３】ＯＡ機器管理手段１１によって、ネットワーク上に接続されている各ＯＡ機器の消耗品情報及び総計情報を、自動発注端末装置１のネットワークの入出力装置を使って取得する（ステップＳ２３）。実際には、これらの情報を自動発注端末装置１の記憶装置（ＨＤＤ）に記録しておく。ステップＳ２４において、消耗品情報及び総計情報が取得できない場合には、自動発注端末装置１の記憶装置（ＨＤＤ）から過去の消耗品情報及び総計情報を取得する（ステップＳ２５）。

【００２４】次に、供給量計算手段１２によって、各消耗品の供給量を計算する（ステップＳ２６）。消耗品情報から計算する場合には、実施例１のステップＳ４と同様に、総計情報から計算する場合には、実施例２のステップＳ１６と同様に処理を行う。過去の消耗品情報及び総計情報から計算する場合には、まず、過去の消耗品情報及び総計情報から平均供給量を求める。例えば、図１０（Ｂ）における複写機の場合、１日の平均供給量を求めると、記録紙Ａ４で１１６７枚，記録紙Ａ３で６６枚となり、この平均供給量を必要な供給量とする。また、トナーや感光体のような消耗品は、供給量を常に１個とする。

【００２５】

【発明の効果】請求項１の発明に対応する効果：ネットワークに接続されているＯＡ機器の消耗品を自動的に発注することにより、消耗品の不足を事前に防ぎ、消耗品の不足により生じる印刷或いはコピーの作業の中断を防ぐことができる。

【００２６】請求項２の発明に対応する効果：請求項１の発明に対応する効果に加えて、ＯＡ機器の供給装置の故障により正確に消耗品の残量の情報が取得できない場合でも、印刷結果，履歴等の総計情報から必要な供給量が計算でき、消耗品の不足を防ぐことができる。

【００２７】請求項３の発明に対応する効果：ネットワークに接続されているＯＡ機器の消耗品を自動的に発注することにより、消耗品の不足を事前に防ぎ、消耗品の不足により生じる印刷或いはコピーの作業の中断を防ぐことができる。特にＯＡ機器の故障により消耗品の情報及び履歴等の総計情報が取得できない場合でも、過去の消耗品の情報及び履歴等の総計情報から必要な供給量が計算でき、消耗品の不足を防ぐことができる。

【図面の簡単な説明】

【図１】　本発明における自動発注システムの構成例を示す図である。

【図２】　本発明における自動発注システムを説明するためのブロック図である。

【図３】　本発明の自動発注システムにおける第１の実施例を説明するためのフロー図である。

【図４】　ＯＡ機器の消耗品の在庫情報の構成を示す図である。

【図５】　ＯＡ機器の消耗品の在庫情報のデータの例を示す図である。

【図６】　ＯＡ機器の消耗品情報の構成示す図である。

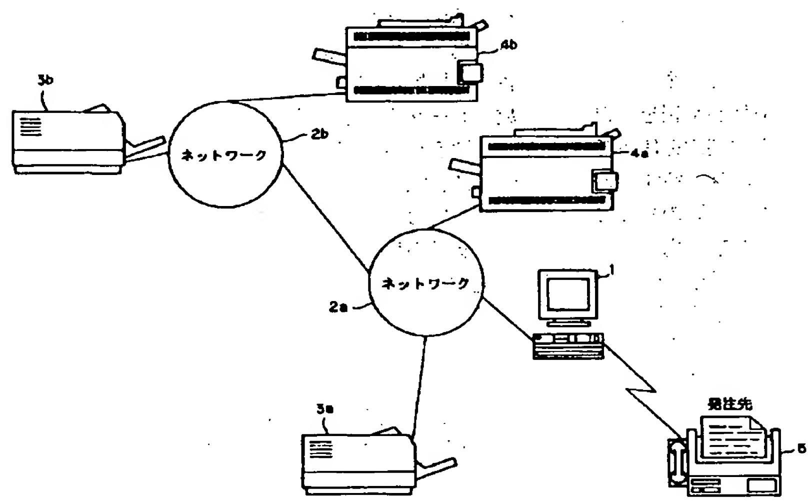
【図７】　ＯＡ機器の消耗品情報のデータの例を示す図である。

【図８】　本発明の自動発注システムにおける第２の実施例を説明するためのフロー図である。

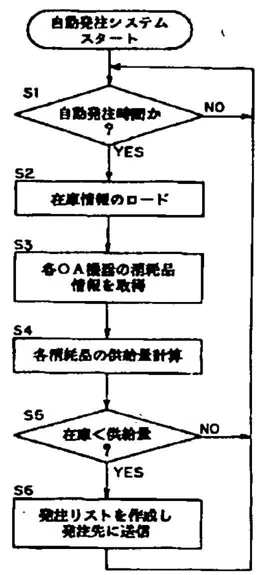
【図９】　印刷結果を表す総計情報の構成を示す図であ

る。
【図１０】　印刷結果を表す総計情報のデータの例を示す図である。
【図１１】　本発明の自動発注システムにおける第３の実施例を説明するためのフロー図である。
【符号の説明】
１…自動発注端末装置、２ａ，２ｂ…ネットワーク、３ａ，３ｂ…プリンタ、４ａ，４ｂ…複写機、５…発注先、１０…在庫情報管理手段、１１…ＯＡ機器管理手段、１２…供給量計算手段、１３…欠品検出手段、１４…発注手段。

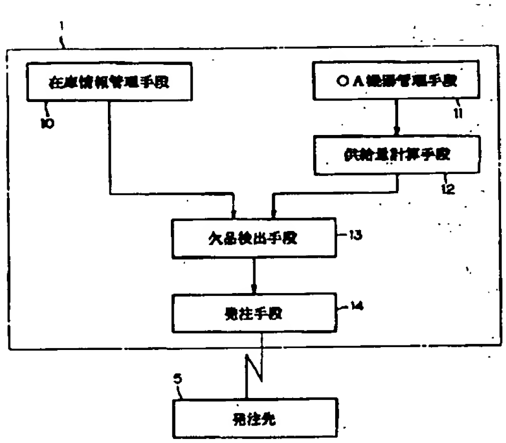
【図１】



【図３】



【図２】



【図５】

サプライコード	サプライ名	在庫量	発注中の量
0001	記録紙Ａ４	25000枚	0枚
0002	記録紙Ａ３	10000枚	10000枚
0010	プリンタ用トナー	10個	0個
0020	複写機用トナー	5個	5個
0100	プリンタ用感光体	5個	0個
0200	複写機用感光体	1個	4個
⋮	⋮	⋮	⋮

【図４】

サプライコード	サプライ名	在庫量	発注中の量

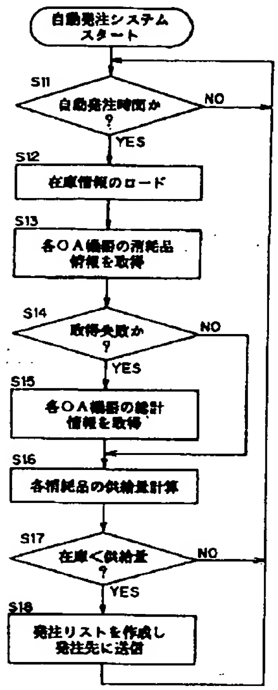
【図６】

サプライ名	最大供給量	残量

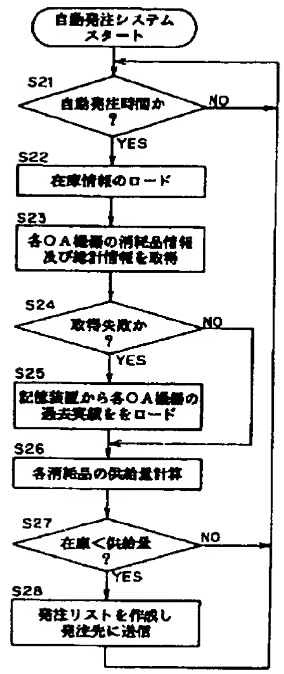
【図7】

サプライ名	最大供給量	残量
記録紙A４	3000枚	1500枚
記録紙A３	250枚	50枚
プリンタ用トナー	100%	50%
プリンタ用感光体	30000枚印刷可能	15000枚印刷

【図8】



【図11】



【図9】

印刷日付	ユーザ名	印刷名	出力用紙	出力枚数

【図10】

(A)

プリンタ

印刷日付	ユーザ名	印刷名	出力用紙	出力枚数
8/1	matsui	名簿.doc	A４	7枚
8/1	kiyohara	月間報告.doc	A４	10枚
8/1	takahashi	テーマ報告	A４	3枚
8/1	nagashima	source.cpp	A４	30枚
8/1	不明	道案内図	A３	5枚
⋮	⋮	⋮	⋮	⋮

(B)

複写機

印刷日付	ユーザ名	印刷名	出力用紙	出力枚数
8/1	――	――	A４	1500枚
8/1	――	――	A３	100枚
8/2	――	――	A４	1000枚
8/2	――	――	A３	50枚
8/3	――	――	A４	1000枚
8/3	――	――	A３	50枚
⋮	⋮	⋮	⋮	⋮

US 20010001582A1

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Walker (43) **Pub. Date: May 24, 2001**

(54) **PROJECTION SCREEN APPARATUS INCLUDING HOLOGRAPHIC OPTICAL ELEMENT**

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Publication Classification

(51) **Int. Cl.**^{7} **G03B 21/56**
(52) **U.S. Cl.** **359/443**; 359/460

(57) **ABSTRACT**

A screen apparatus includes a holographic optical element and a diffuser. The holographic optical element may be constructed using standard techniques known in the field of holography. The holographic optical element may be used to replace a typical Fresnel lens used in projection screen apparatuses. In operation, the holographic optical element receives image light from an image engine or projector and redirects the image light to the diffuser for scattering. The holographic optical element can be designed to substantially collimate. converge, or diverge the image light. The combination of the holographic optical element and the diffuser provides improved illumination uniformity that can be perceived by a viewer as the viewer moves in directions transverse to the screen apparatus. The screen apparatus may be designed to provide improved illumination uniformity to optimized or optimal locations in a viewing region. The screen apparatus may be advantageously employed in display apparatuses.

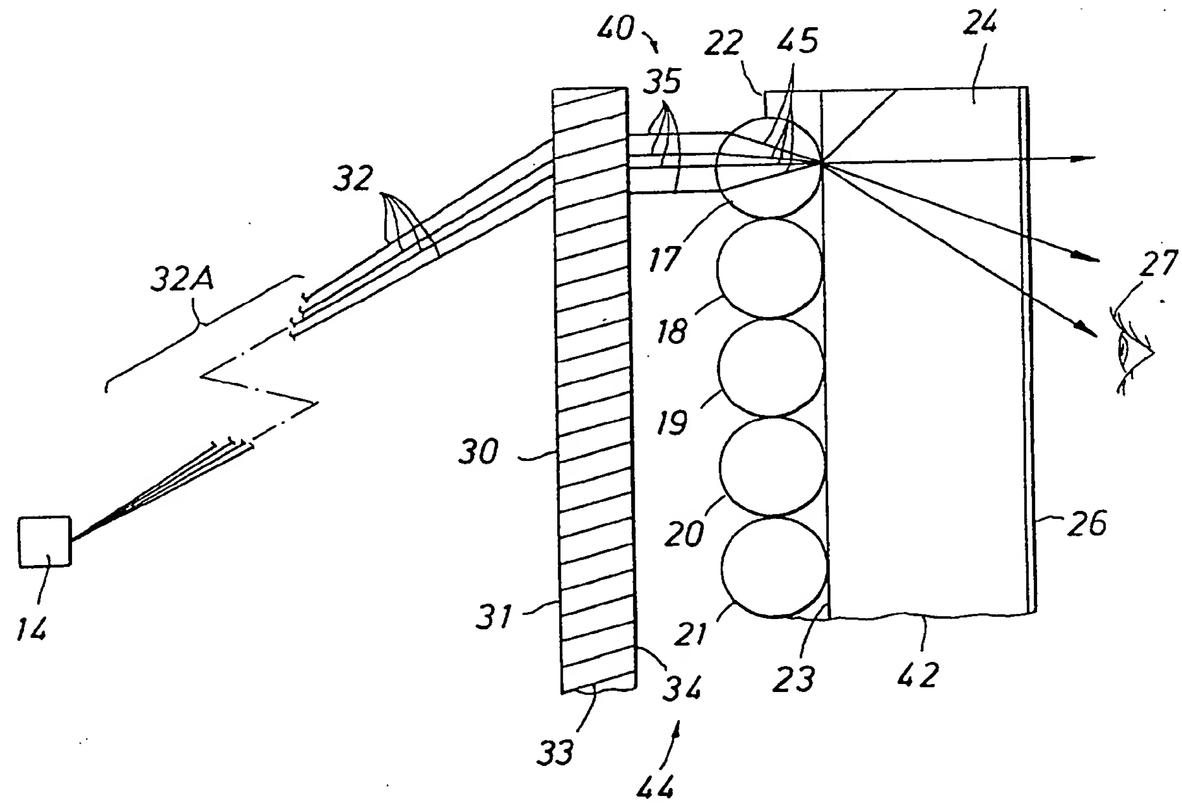


FIG. 1
(PRIOR ART)

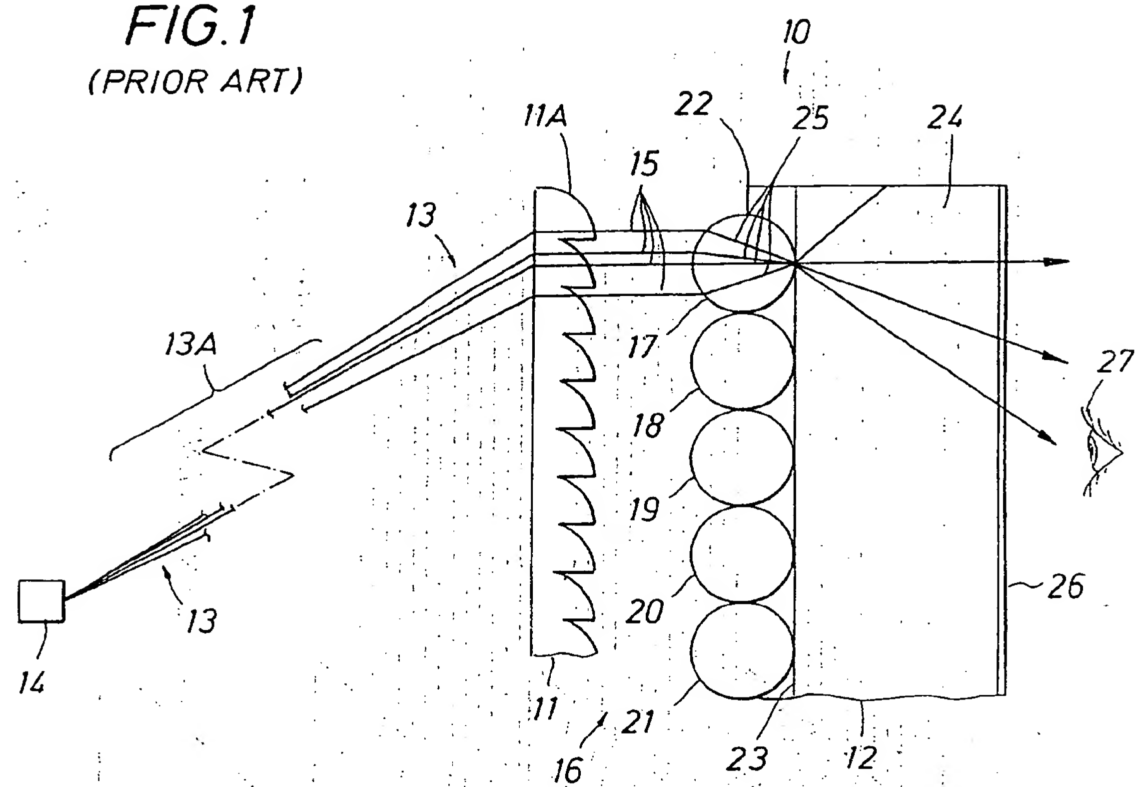
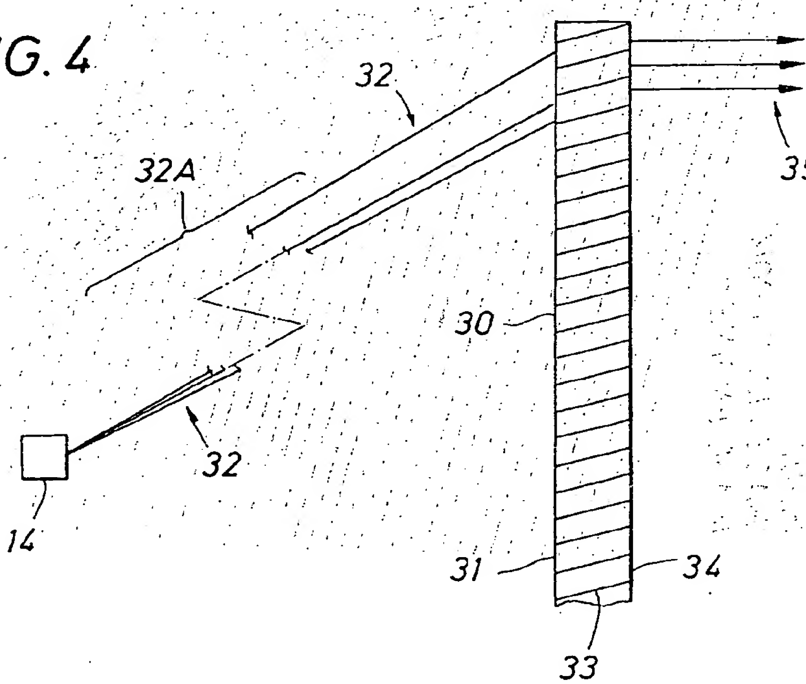


FIG. 4



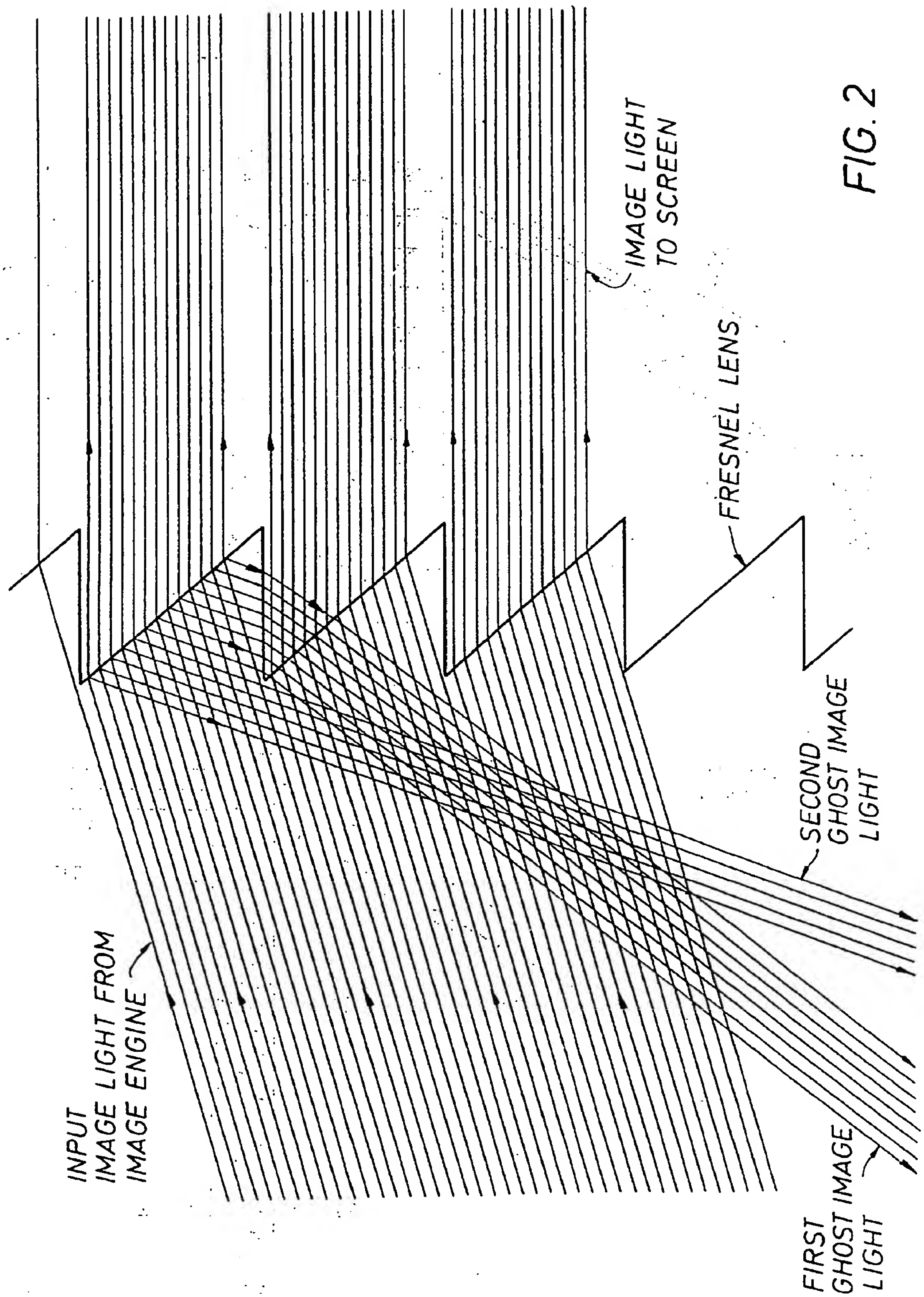


IMAGE LIGHT
TO SCREEN
FRESNEL LENS
SECOND
GHOST IMAGE
LIGHT
INPUT
IMAGE LIGHT FROM
IMAGE ENGINE
FIRST
GHOST IMAGE
LIGHT

FIG. 2

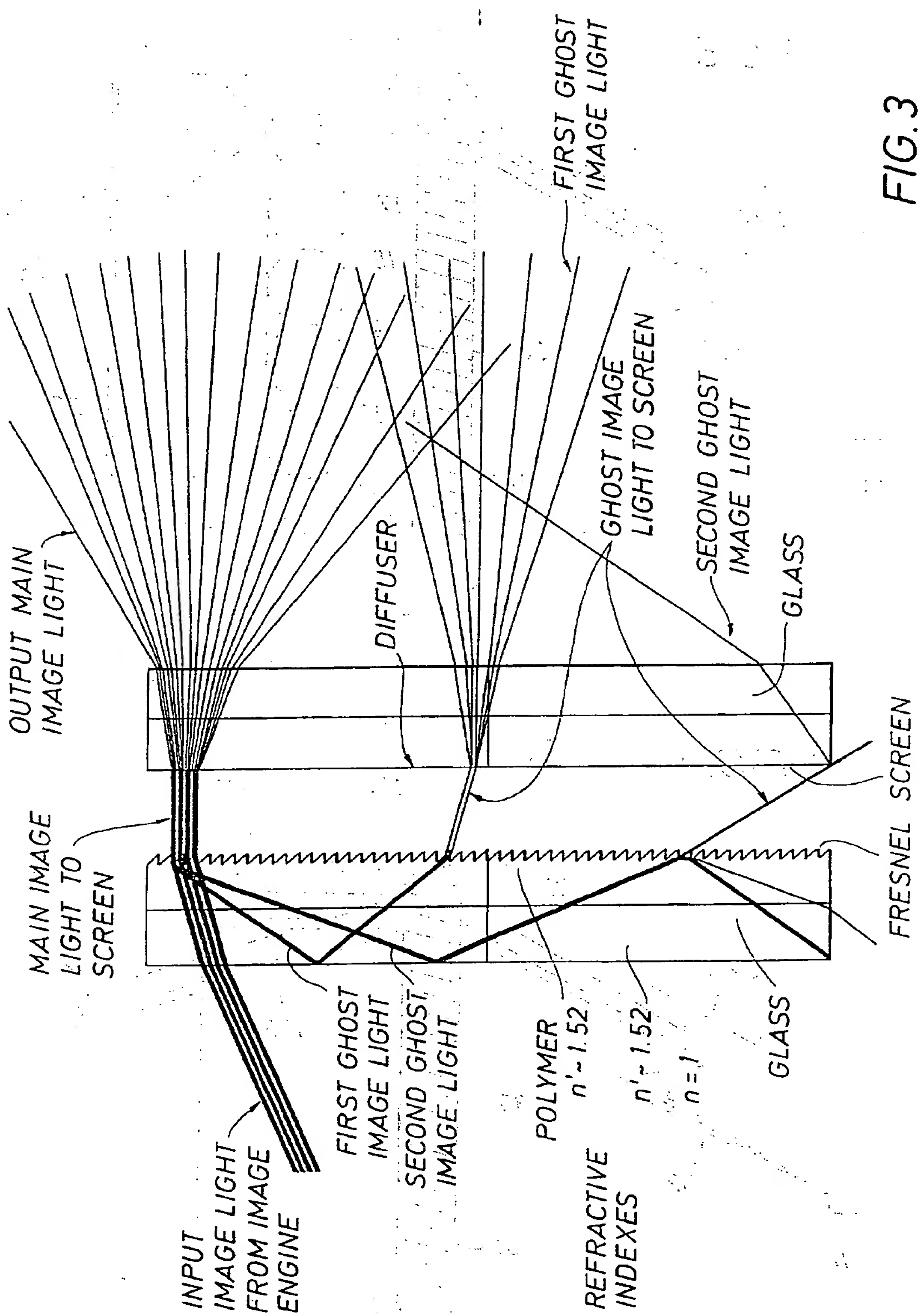

INPUT IMAGE LIGHT FROM IMAGE ENGINE
MAIN IMAGE LIGHT TO SCREEN
OUTPUT MAIN IMAGE LIGHT
DIFFUSER
FIRST GHOST IMAGE LIGHT
SECOND GHOST IMAGE LIGHT
POLYMER n'~1.52
n'~1.52
n=1
REFRACTIVE INDEXES
GLASS
GHOST IMAGE LIGHT TO SCREEN
SECOND GHOST IMAGE LIGHT
GLASS
FIRST GHOST IMAGE LIGHT
SCREEN
FRESNEL

FIG. 3

FIG. 5

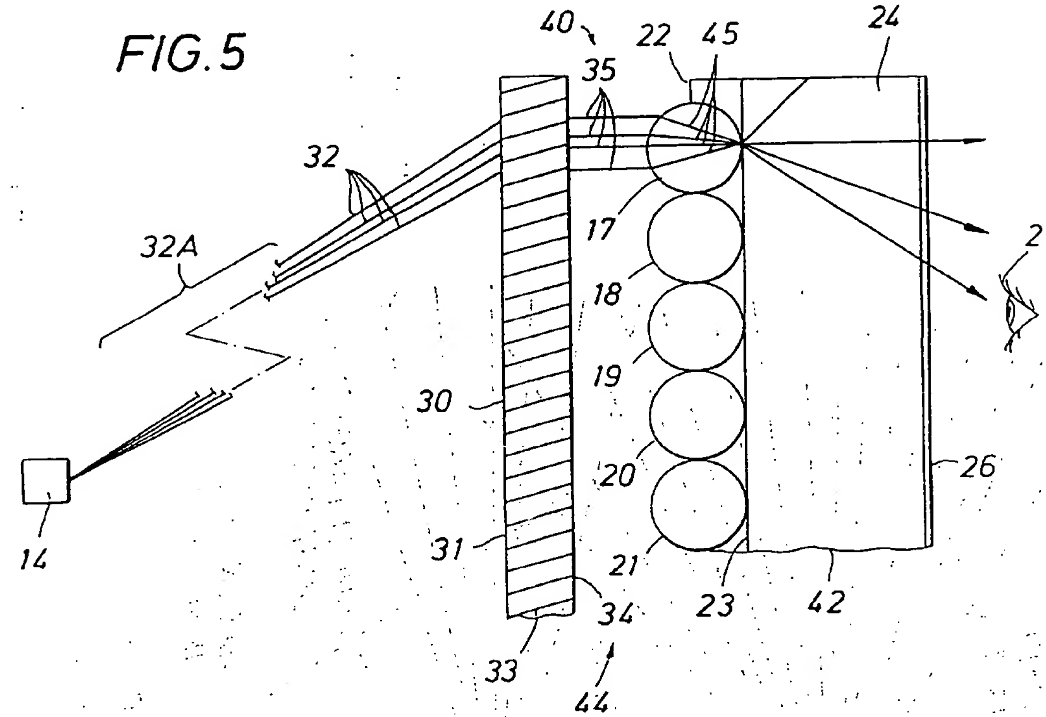
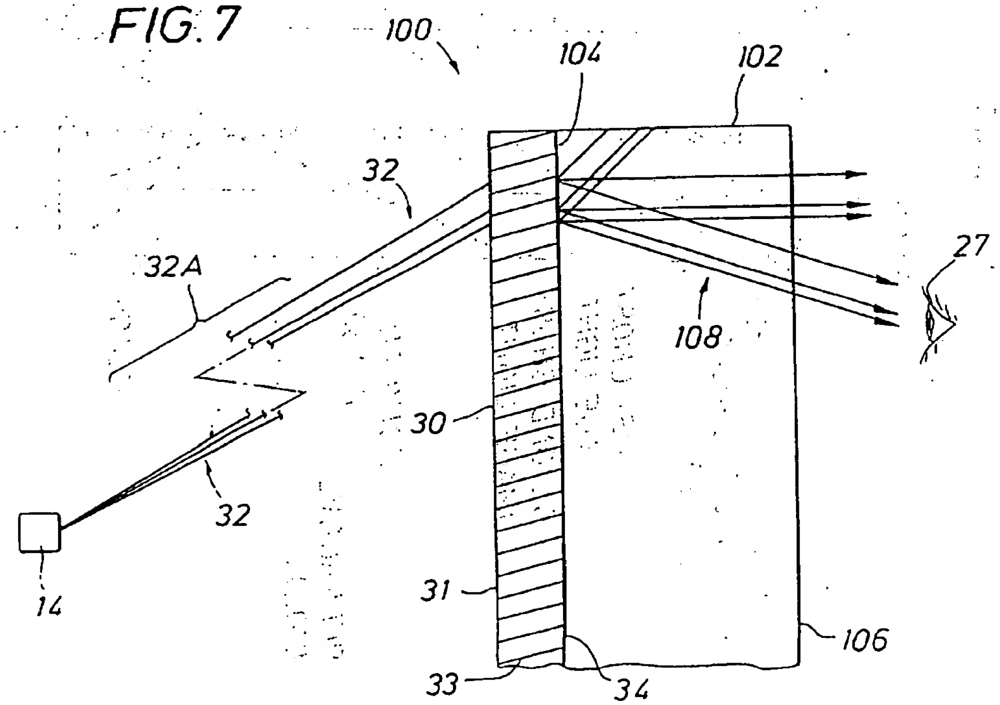

40
22
45
24
35
32
17
27
32A
18
19
30
20
26
31
21
14
23
42
34
33
44

FIG. 7


100
104
102
32
32A
27
108
30
32
14
31
106
33
34

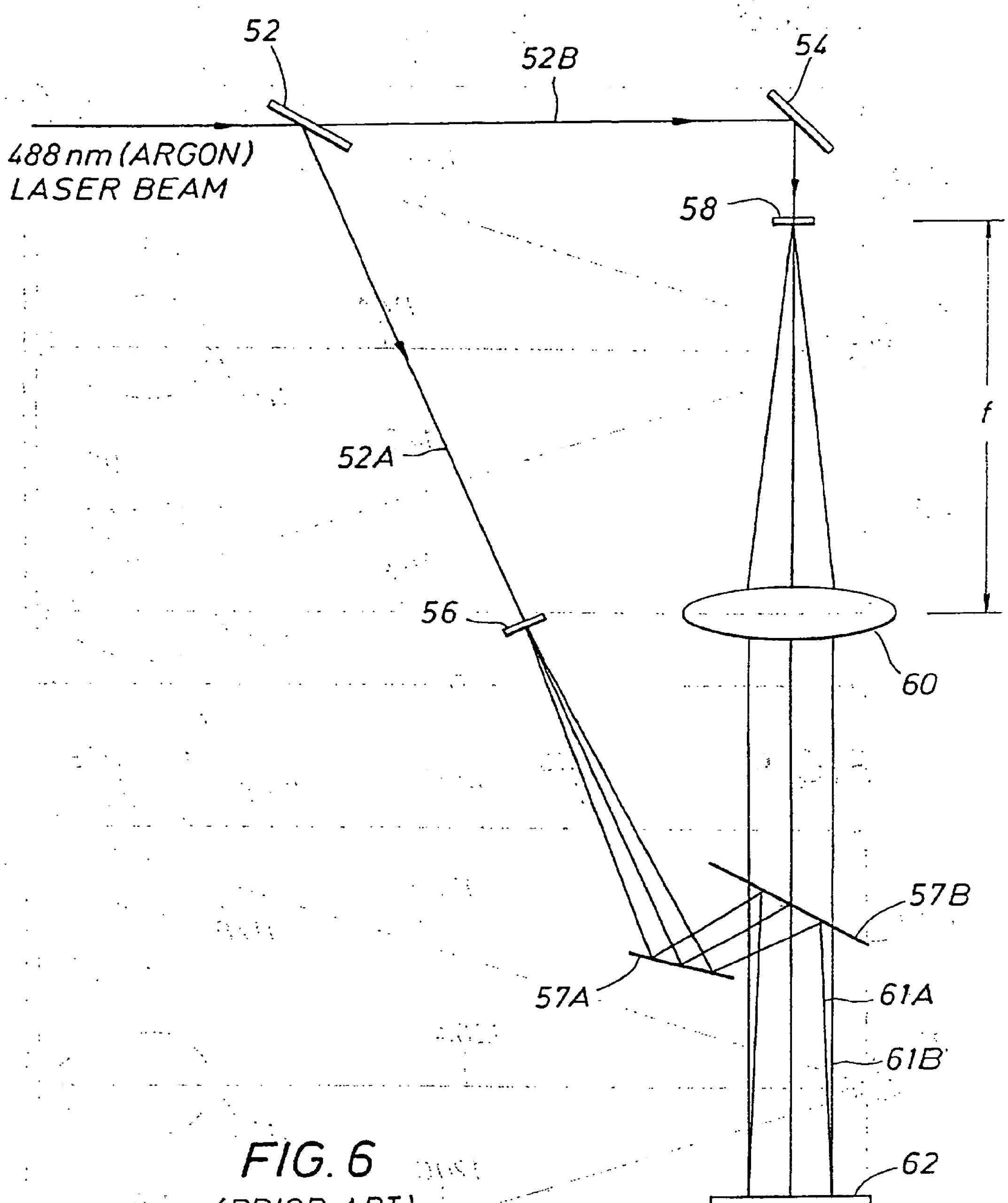


FIG. 6
(PRIOR ART)

FIG. 8

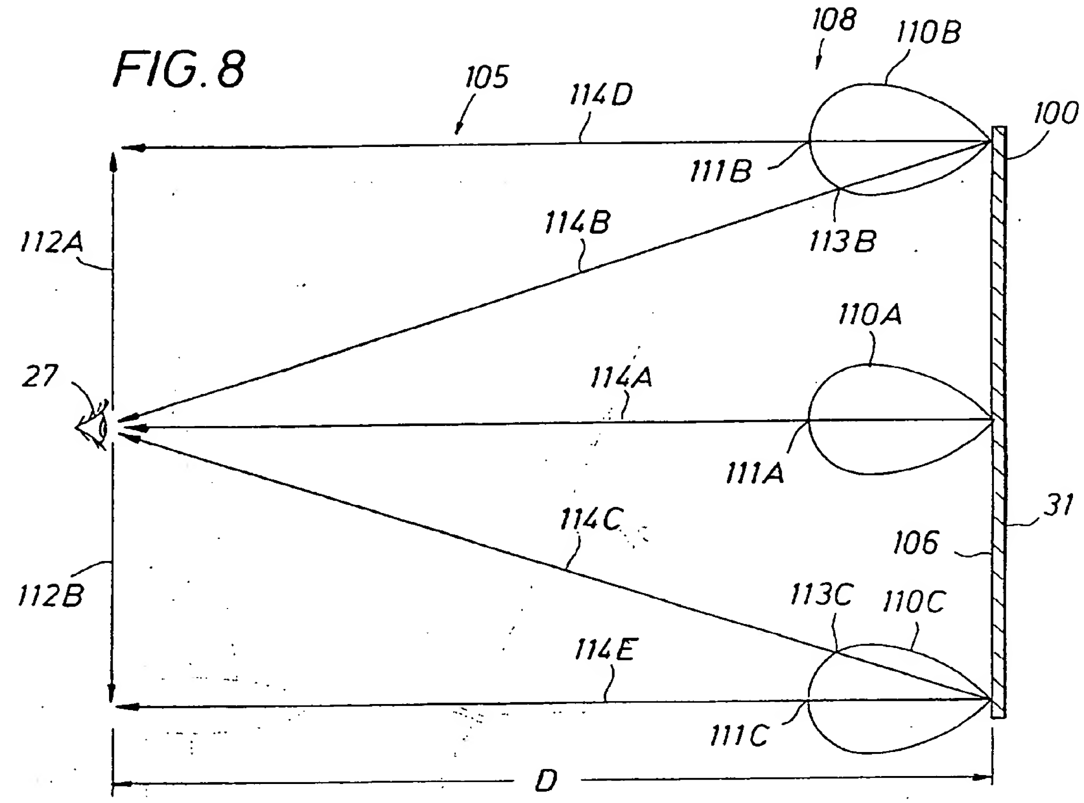

108
110B
105
114D
100
111B
113B
114B
112A
110A
27
114A
111A
31
114C
106
112B
113C
110C
114E
111C
D

FIG. 9

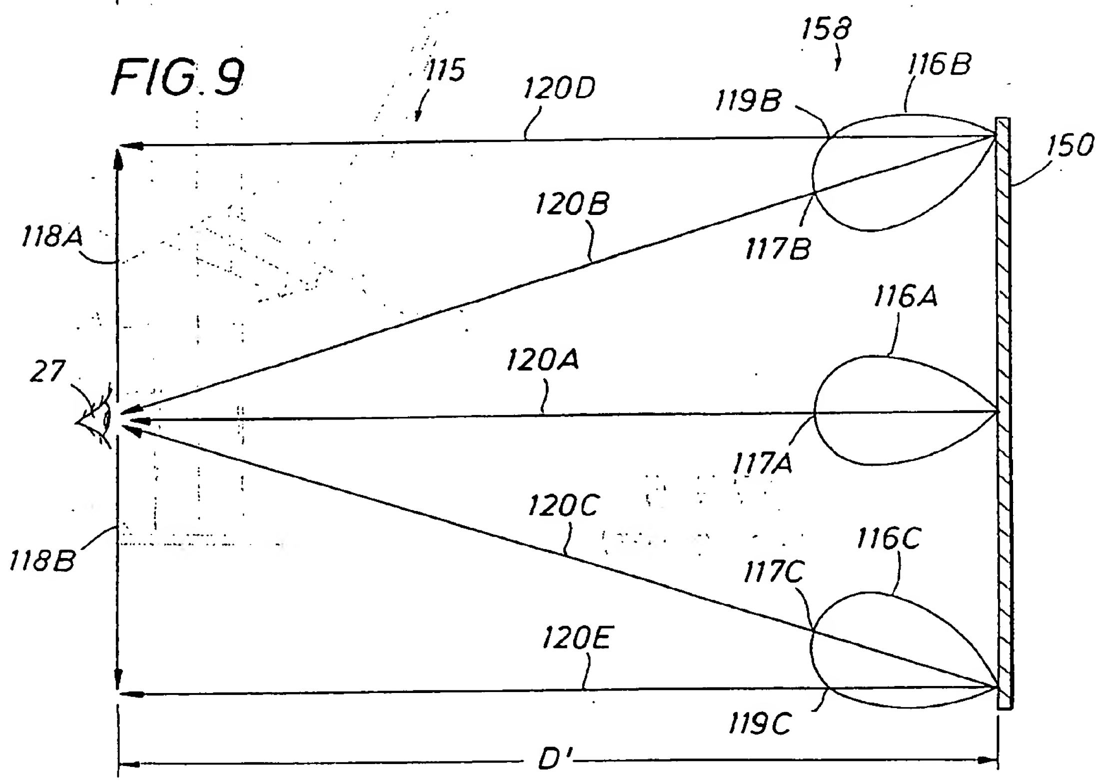

158
116B
115
120D
119B
150
120B
117B
118A
116A
120A
27
117A
120C
118B
116C
117C
120E
119C
D'

FIG. 10

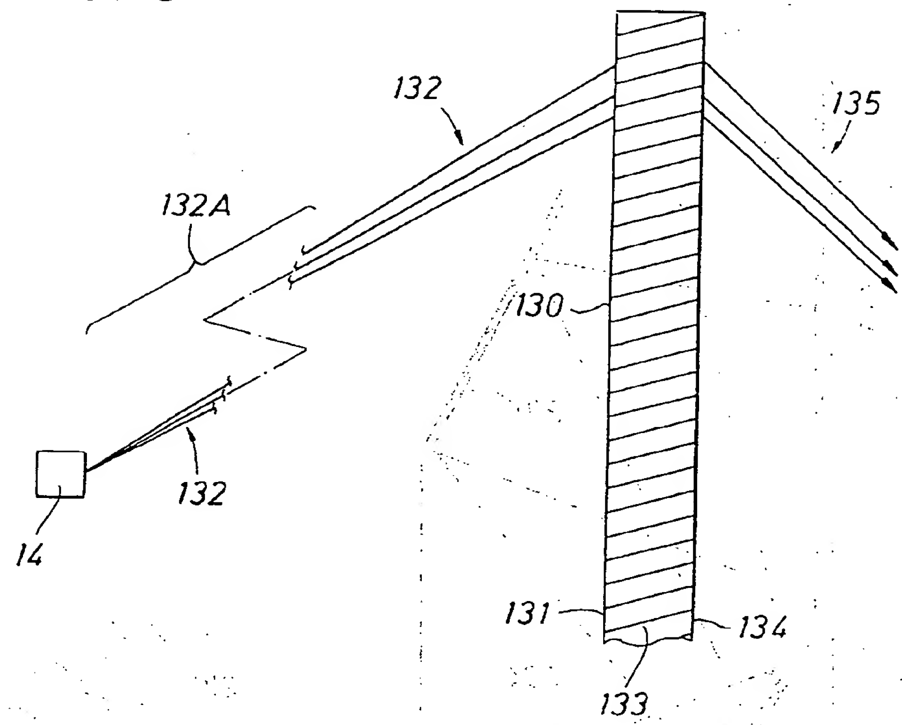
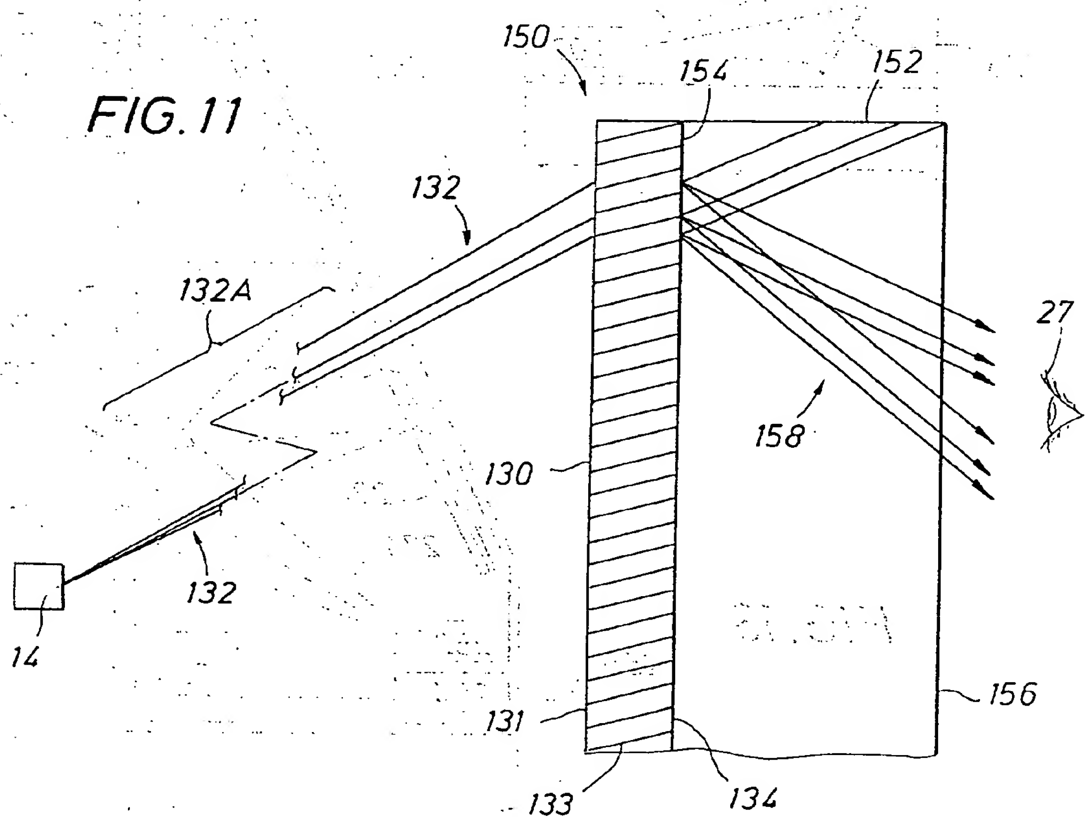

132
135
132A
130
132
14
131
134
133

FIG. 11


150
154
152
132
132A
27
158
130
132
14
156
131
133
134

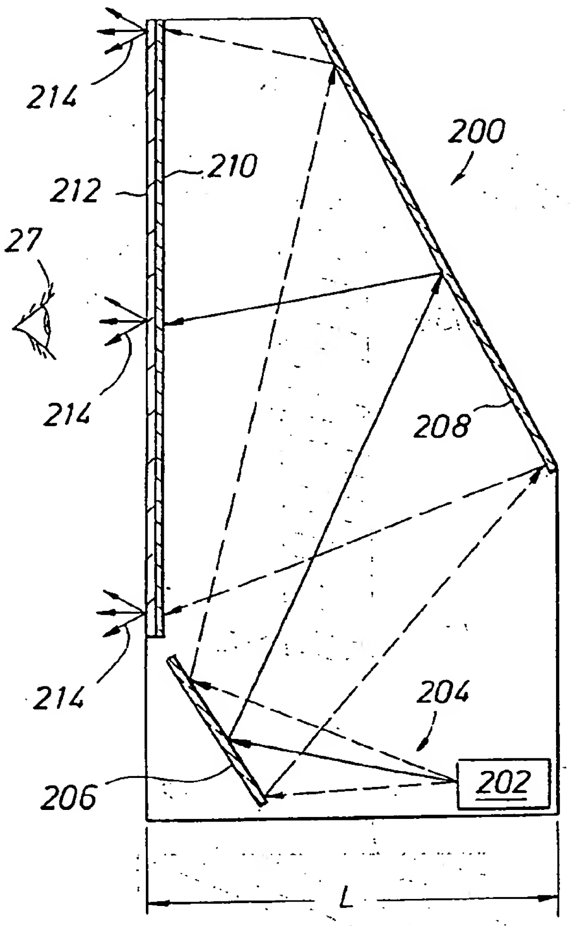

214
212
210
200
27
214
208
214
204
206
202
L

FIG. 12

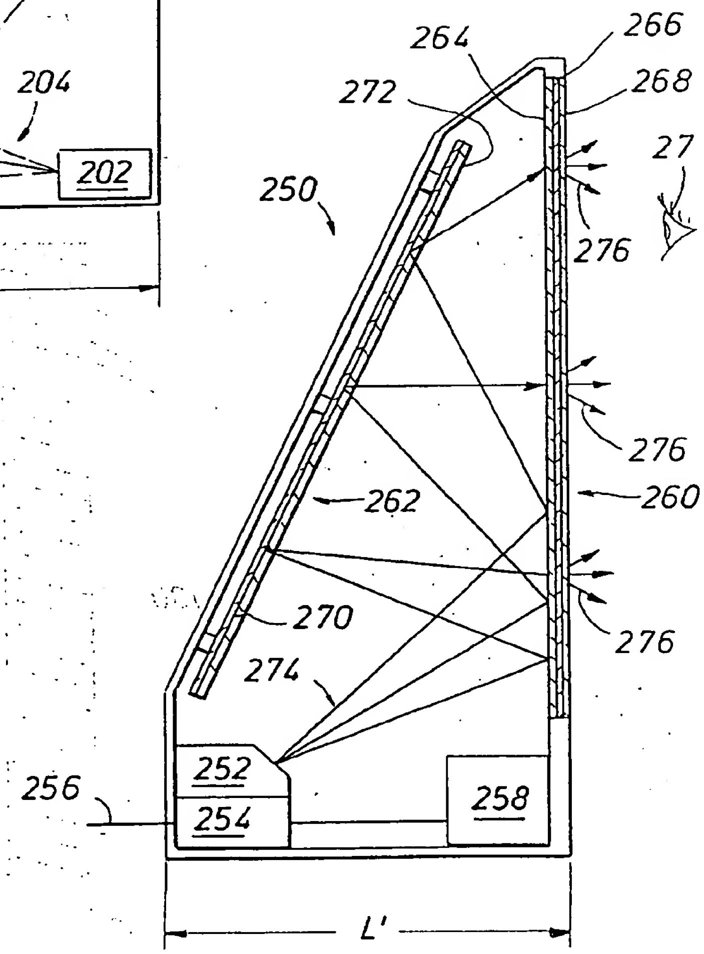

264
266
268
272
27
250
276
276
262
260
270
276
274
256
252
254
258
L'

FIG. 13

PROJECTION SCREEN APPARATUS INCLUDING HOLOGRAPHIC OPTICAL ELEMENT

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to projection systems and projection screens and, more particularly, to a projection screen apparatus that provides improved image illumination uniformity.

[0003] 2. Description of Related Art

[0004] Light projection is used to display images on large surfaces, such as large computer displays or television screens. In front projection systems, an image beam is projected from an image source onto the front side of a reflection-type, angle transforming screen, which then reflects the light toward a viewer positioned in front of the screen. In a rear projection system, the image beam is projected onto the rear side of a transmission-type, angle transforming screen and transmitted toward a viewer located in front of the screen.

[0005] Referring to **FIG. 1**, wide angle projection systems that include a screen apparatus **10** are known to optimally use a conventional Fresnel lens **11** in combination with some diffusing element, such as a substrate covered with glass beads (e.g., a type of diffuser or diffusive screen) **12**. The combination forms an imaging screen that produces an image. The Fresnel lens **11** and the diffuser **12** are held in relatively rigid or semi-rigid spaced apart relation to assure proper operation of the combination. Such screens, known generally in the art as "black matrix bead" or "BMB" screens, are commercially available from Minnesota Mining & Manufacturing Company and others. Fresnel lenses are sold by Fresnel Optics and are manufactured by Minnesota Mining & Manufacturing Company, for example, as used in devices such as overhead projectors. The Fresnel lens **11** element is constructed to provide the optical properties of a much thicker lens, however, with smaller size and weight. Concentric steps or discontinuities **11A** allow these optical and physical properties to be realized. Each of the steps has a curved profile, in cross-section, that exhibits optical power to redirect incident light **13**. The cut-out sections that define the steps reduce the overall size and weight.

[0006] In **FIG. 1**, the Fresnel lens **11** receives the incoming light **13** from a projection image engine or image projector **14** (e.g., a liquid crystal display imager, a light source, and a projection lens that produce image light in response to input video or other signals). The break in the light path of the light **13** shown in **FIG. 1** is included to recognize that the light **13** may be processed or filtered, for example, projected by the projection or other lens (not shown), and is generally indicated by numeral **13A**. The screen apparatus **10** and the image engine **14** are arranged such that a light beam exiting the Fresnel lens **11** is collimated, as shown by parallel rays of light **15**. The collimated rays **15** pass across an air gap **16** to a matrix of glass beads **17-21** in the diffuser **12**. The glass beads **17-21** are mounted upon an adhesive black mask layer **22** that is on a front surface **23** of a substrate **24** of the diffuser **12**. As the collimated light rays **15** strike any of the glass beads **17-21**, the rays are focused as light **25** in **FIG. 1**. The substrate **24** is light transparent so that a viewer **27** can see an image from the light **25** that passes through a surface **26** (e.g., an acrylic, polystyrene, other polymer or like surface) of the screen apparatus **10**. The screen apparatus **10** can be an "intelligent" television screen, having a large diagonal dimension, for example, substantially 60 inches, or a computer monitor screen.

[0007] For wide angle projection, there are currently no satisfactory methods of collimating light at a display screen. The conventional Fresnel lens **11** may create objectionable shadows and ghosts (i.e., ghost images from light scattered in undesired directions) that degrade the display image. The discontinuities in the Fresnel lens **11** lead to shadows and ghosts being introduced on illumination of the screen apparatus **10**. The formation of a ghost image from discontinuous surfaces of a Fresnel lens is schematically illustrated in **FIG. 2**, and its appearance on the viewing side of a Fresnel lens/diffuser combination screen is schematically illustrated in **FIG. 3**. For discussion on the disadvantages of such stepped lenses, see *Antenna Theory* by Constantine A. Balanis, Harper and Row, New York, 1982, p. 650 and *Antenna Engineering Handbook,* H. Jasik (ed.) (Chapter 14 by S. B. Cohn), McGraw-Hill, New York, 1961, pp. 14-1 to 14-43. Moreover, the Fresnel lens **11** is also disadvantageous because it may be relatively expensive, easily damaged, have visible rings, and cannot be laminated (e.g., index matched) on both sides. Removing the Fresnel lens **11** and relying only on the diffusive screen **12** itself to achieve uniformity may result in a "hot spot" in the center of the screen and wasted light diffused out of the field of view of the viewer **27**. The air gap **16** between the Fresnel lens **11** and the glass beads **17-21** also prevents the screen apparatus **10** from being as compact or as mechanically stable as might otherwise be possible.

[0008] The present invention is directed to overcoming or substantially limiting some or all of the above shortcomings of the Fresnel lens/diffuser combination screens, and the occurrence of the hot spot when no Fresnel lens is used.

SUMMARY OF THE INVENTION

[0009] In one aspect, the invention features a screen apparatus. The screen apparatus includes a holographic optical element adapted to receive image light and to redirect the image light. The screen apparatus also includes a diffuser adapted to receive the redirected image light from the holographic optical element and to scatter the redirected image light.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Other objects and advantages of the invention will become apparent upon reading the following detailed description and upon reference to the drawings in which:

[0011] **FIG. 1** is a side, cross-sectional view of a prior art BMB projection screen that uses a Fresnel lens in combination with a spaced apart bead-covered diffuser.

[0012] **FIG. 2** is a schematic illustration of the formation of ghost image light from a Fresnel lens.

[0013] **FIG. 3** is a schematic illustration of ghost image light appearing on the viewing side of a Fresnel lens/diffuser combination screen.

[0014] **FIG. 4** is a side, cross-sectional view of a holographic optical element collimating light in accordance with an embodiment of the invention.

[0015] FIG. 5 is a side, cross-sectional view of a screen apparatus in accordance with the embodiment in FIG. 4.

[0016] FIG. 6 is a plan view of a prior art system for forming a holographic optical element.

[0017] FIG. 7 is a side, cross-sectional view of a screen apparatus in accordance with another embodiment of the invention.

[0018] FIG. 8 is a plan view of the screen apparatus in FIG. 7 schematically showing image light features in a viewing region.

[0019] FIG. 9 is a plan view of a screen apparatus schematically showing image light features in a viewing region in accordance with another embodiment of the invention.

[0020] FIG. 10 is a side, cross-sectional view of a holographic optical element converging light in accordance with the embodiment in FIG. 9.

[0021] FIG. 11 is a side, cross-sectional view of a screen apparatus in accordance with the embodiment in FIGS. 9 and 10.

[0022] FIG. 12 is a side, cross-sectional view of a display apparatus in accordance with another embodiment of the invention.

[0023] FIG. 13 is a side, cross-sectional view of another display apparatus in accordance with another embodiment of the invention.

[0024] While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the description herein of specific embodiments is not intended to limit the invention to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0025] Illustrative embodiments of the invention are described below. In the interest of clarity, not all features of an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort, even if complex and time-consuming, would be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

[0026] The present invention relates to an improved screen apparatus, for example, a projection screen, that may be employed in a front or rear projection system, such as a television, or in a computer monitor. Referring to FIGS. 4 and 5, a holographic optical element (HOE) 30 is included in a screen apparatus 40 (FIG. 5) in accordance with a first embodiment of the invention. The HOE 30 may be used to replace the Fresnel lens 11 discussed above, performs a similar function as the Fresnel lens 11, but has distinct advantages that will be described below. The HOE 30 is recorded and processed (e.g., developed and possibly baked) to substantially collimate incoming image light 32 received from the image engine 14. Baking may be required for certain HOE (e.g., photopolymer) materials used to make the HOE 30, such as some materials that can be obtained from DuPont. Other types of HOE materials used to make the HOE 30, such as those for making surface relief, surface kineform, or embossed HOEs, may employ other methods that do not include baking. The image engine 14 may be similar to image engines described in prior, co-owned U.S. patent application Ser. No. 08/730,818, filed Oct. 17, 1996, by Richard M. Knox, entitled "Image Projection System Engine Assembly," which is incorporated by reference herein in its entirety. The image light 32 is similar to the image light 13 in FIG. 1, with a break labeled 32A in the light path being analogous to the break 13A in FIG. 1. For example, the light 32 may be processed or projected by a projection or other lens (not shown) to the HOE 30, as generally indicated by the numeral 32A. The incoming image light 32 may be diverging as it strikes the HOE 30. The light 32 passes through an input surface 31 and then an output surface 34 of the HOE 30 as substantially collimated light 35. The surfaces 31, 34 form a pair of opposed surfaces.

[0027] The HOE 30 may be formed using standard reference and object beam interference techniques known in the field of holography. One possible optical setup among many other possible setups that may be used to form the HOE 30 is depicted in FIG. 6, as will be appreciated by those skilled in the art. Light from a coherent light source (not shown), for example, an argon laser, is split by a variable beamsplitter 52 into two beams. One branch 52A of the split light passes through a first spatial filter 56 and another branch 52B is redirected by a reflector or mirror 54 through a second spatial filter 58. The light in the branch 52A passing through the spatial filter 56 is known in the art as the "reference" beam and the light in the branch 52B passing through the spatial filter 58 is known as the "object" beam. Such terms as reference and object would be considered somewhat arbitrary in other implementations that may be used to record holograms, as will be appreciated by those skilled in the art. The spatial filters 56, 58 produce substantially uniform light intensity in a transverse direction across their output. The reference and object beams 52A, 52B both diverge after passing through the spatial filters 56, 58. The light from the spatial filter 56 is reflected from a substantially 100% reflective mirror 57A to a substantially 50% reflective/50% transmissive (e.g., silvered) mirror 57B. A portion 61A of the light 52A reflects from the mirror 57B and then impinges on a photosensitive material 62 (e.g., a photographic plate or photopolymer materials, such as those available from DuPont or Polaroid) that is used to record the HOE 30. The light passing through the spatial filter 58 is first directed to pass through a fast (e.g., F/1) collimating lens or collimator 60 spaced at approximately its focal length (f) from the spatial filter 58. This results in approximately collimated light being produced, a portion 61B of which then passes through the mirror 57B and is incident on the photosensitive material 62. The reference and object beams 52A, 52B (i.e., the portions 61A, 61B) will interfere with each other to form a hologram as an interference pattern or fringes in the photosensitive material 62, shown generally as numeral 33 in FIGS. 4-5. Such a pattern results because both

the reference beam 52A and the object beam 52B are derived from a substantially coherent source.

[0028] Once the HOE 30 is recorded and developed, it is possible to reproduce the reference beam 52A (i.e., the portion 61A) by simply placing the HOE 30 approximately in its original position and introducing only the same or a similar object beam 52B (i.e., the portion 61B). It is also possible to reproduce the object beam 52B by introducing only the same or a similar reference beam 52A. In the present invention, the emphasis will be mainly on the object beam 52B being reproduced by the same or a similar reference beam 52A, although applications involving reproduction of the reference beam 52A by the object beam 52B in other embodiments will be appreciated by those skilled in the art.

[0029] For a transmission-type hologram, the introduction of the reference beam will reproduce the object beam, which is transmitted by the recorded hologram. The reproduced, substantially collimated object beam light is directed into, what is termed in the art, the "first" order of diffraction of the reference beam. A portion of the reference beam (approximately 4%) will pass through the hologram in other orders, most significantly in the "zero" order of diffraction of the reference beam.

[0030] After recording and developing, the hologram may or may not be baked. Baking is preferable in some embodiments (e.g., if DuPont photopolymer is used), however, as it allows the interference fringes 33 produced by the interfering light to be stabilized (i.e., substantially fixed). After baking, the hologram will perform substantially similarly to its performance before baking. The hologram recorded in such a manner may be used in the screen apparatus 40 in FIG. 5 as the HOE 30 to substantially collimate the image light 32 as the light 35. The image light 32 is introduced to the HOE 30 similarly to the reference beam light in FIG. 6, i.e., at approximately the same angle and divergence.

[0031] Although the HOE 30 is initially recorded with substantially coherent laser light of narrow wavelength or color, white light, "quasi"-white light, or other colored light from the image engine 14 will be nearly collimated when introduced in place of the reference beam light used to record the HOE 30. This is true, even though the HOE 30 may exhibit some chromatic dispersion. Quasi-white light, in the context of the present invention, refers to light output from a light source that may be deficient in one or more colors, but, nevertheless, produces substantially white light.

[0032] Referring again to FIG. 5, the screen apparatus 40 includes a diffuser or diffusive screen 42 much like the diffuser 12 shown in FIG. 1. The collimated light 35 is focused by the glass bead 17 as light 45 and viewed as an image by the viewer 27 from the image light 45 that passes through the surface 26 after passing through the substrate 24, as described above. The diffuser 42, in the particular embodiment illustrated, is held in spaced apart relation to the HOE 30, spaced by a small air gap 44. The effects of the chromatic dispersion discussed above, that spreads light colors differently, may be minimized by making the air gap 44 as narrow as possible (e.g., on the order of microns) or by eliminating it altogether, as will be appreciated by those skilled in the art. Moreover, the use of a no-beaded screen, such as a bulk diffusing screen, may help avoid or reduce some of these chromatic dispersion effects, as will be discussed below.

[0033] The HOE 30 offers distinct advantages over the Fresnel lens 11 in FIG. 1 for collimating the image light. There is no ghost image, light or shadowing, such as that produced by the Fresnel lens 11. An air gap, like the air gap 44, is not necessarily required, or may be substantially reduced, depending on screen apparatus design, as will be described below. The HOE 30/diffuser 42 combination may be both flat and flexible. There may be no need to hold the HOE 30 and the diffuser 42 in rigid or semi-rigid spaced apart relation to assure proper operation. Moreover, the HOE 30 may be lighter in weight and cheaper than the typical Fresnel lens 11.

[0034] Referring to FIG. 7, a screen apparatus 100 is illustrated in accordance with a second embodiment of the invention. The screen apparatus 100 includes the HOE 30 layered or coated on, bonded or adjacent to, or otherwise suitably applied to, a diffusive screen or diffuser 102. Suitable bonding may be achieved with an index matching optical adhesive or material (not shown) applied between the surface 34 of the HOE 30 and a first surface 104 of the diffuser 102, as will be appreciated by those skilled in the art. The diffuser 102 may be formed of a mixture of any two (or more) appropriate immiscible materials having different indices of refraction. An example of such materials could be two immiscible polymers that have indices of refraction $n=1.5$ and $n'=1.52$, respectively. Another possible material for the diffuser 102 includes TiO_2 or other like materials that, when dispersed as particles or particulate clusters of appropriate size in polymer materials (e.g., a polymer matrix), such as acrylic or other like materials, can act as image light scatterers. The lighter weight of the immiscible materials will form a distribution of spaced apart globules (not shown) of appropriate size within the higher weight material. Each individual globule will tend to stay together due to surface tension effects. These globules, when incorporated in the diffuser 102, will act as light scatterers for light incident. Commercially available diffusers that may be used for the diffuser 102 are available from Nashua in their "MICROSHARP" technology product line, and other diffusers are available from Minnesota Mining & Manufacturing Company among other manufacturers or suppliers. Many types of such diffusers are known in the art.

[0035] In FIG. 7, as before, the imaging light 32 incident on the surface 31 of the HOE 30 is collimated by the HOE 30 on transmission. The collimated light exiting through the surface 34 of the HOE 30 and entering the diffuser 102 through the surface 104 is scattered as it passes through the diffuser 102 as light 108. The effects of chromatic dispersion discussed above should be diminished because there is no air gap or substantially no air gap between the HOE 30 and the diffuser 102 (although a small air gap may be tolerable under certain circumstances in certain embodiments if chromatic dispersion is not too large). The imaging light 108 passes out of the diffuser 102, and the viewer 27, suitably positioned, can see an image from the image light 108 that passes through a surface 106 of the diffuser 102.

[0036] The screen apparatus 100, because of the operation of the HOE 30 and the diffuser 102, will provide relative uniformity of the intensity of the imaging light 108 if the viewer moves his or her head transversely while viewing an image on the surface 106. This may be understood by considering FIG. 8, which schematically illustrates polar plots of forward (power) gain profiles or patterns 110A,

110B, 110C for the light 108 (FIG. 7) exiting the diffuser 102 in a region 105. Similar plots could be constructed for the embodiments shown in FIG. 5, which also provides substantially collimated light upon image light passage through the HOE 30. The forward gain profiles 110A, 110B, 110C have their maxima generally centered in a direction substantially normal to the surface 106 of the diffuser 102 due to the image light 108 being substantially collimated by the HOE 30. A maximum 111A of the gain profile 110A is directed toward the viewer 27, who is located substantially in a central (or other) position for viewing the screen apparatus 100, as generally indicated by the arrow 114A in FIG. 8. The gain profiles 110B, 110C correspond to portions of the light 108 that is scattered from areas of the diffuser 102 near edges of the diffuser 102. These gain profiles do not, however, have their gain profile maxima 111B, 111C directed toward the viewer 27 in this position, as generally indicated by the arrows 114D and 114E. Instead, the light 108, directed toward the viewer 27 from the gain profiles 110B, 110C, have below-maxima values 113B, 113C, as generally indicated by the arrows 114B, 114C.

[0037] The gain profiles 110A, 110B, and 110C in FIG. 8 can give a sense of how image light intensity can vary as the viewer 27 moves transversely in front of the screen apparatus 100. As the viewer 27 moves in either of directions 112A, 112B, at some point, there will be a noticeable increase in one of the gain profile values 110B, 110C of the image light directed toward the viewer 27, and a noticeable decrease in the other. The value of the gain profile 110A will not, however, change that rapidly. Therefore, over a reasonable transverse distance range at a distance "D" in front of the screen apparatus 100, the intensity will be relatively uniform because of the operation of the HOE 30 and the diffuser 102. The distance D can be in a range that would be typical for viewing a particular device, such as a computer monitor, a large or small television screen, or projection screen, in a setting, such as a room. D will, in general, depend on the size of the room, the size of the screen apparatus, and other factors that bear on the particular application.

[0038] FIG. 9, which is similar to FIG. 8, schematically illustrates polar plots of gain profiles 116A, 116B, 116C of scattered image light 158 from a screen apparatus 150 in a region 115. Maxima 117A, 117B, 117C in the gain profiles 116A, 116B, 116C in FIG. 9 are not all forward directed, substantially normal to a viewing surface of the screen apparatus 150. Instead, the maxima in the gain profiles are substantially directed toward a particular (e.g., a central) viewing region or position where the viewer 27 can view an image displayed on the screen apparatus 150. For example, while the gain profile 116A is generally directed along an arrow 120A in the forward direction, the gain profiles 116B, 116C are angularly directed along arrows 120B, 120C, respectively. Gain profile values 119B, 119C for the forward directed image light of the gain profiles 116B, 116C have values further below their respective maxima 117B, 117C compared to the maxima 111B, 111C in FIG. 8. Such gain profiles as 116A, 116B, 116C may be preferable for image viewing and substantially maintaining image light intensity uniformity or illumination uniformity as the viewer 27 moves in transverse directions, i.e., along the directions of arrows 118A, 118B, compared to the gain profiles in FIG. 8. The gain profiles in FIG. 9 can give a sense of maintaining image uniformity better than the gain profiles illustrated in FIG. 8. For example, in FIG. 9, as the viewer 27 moves over a limited range in either of the directions 118A, 118B at a distance "D" from the screen apparatus 150, the variation between the values of the gain profiles 116B, 116C may be less than that between the values of the gain profiles 110B, 110C in FIG. 8. On the other hand, the corresponding variation in the values of the gain profile 116A may be similar to the variation of the values of the gain profile 110A in FIG. 8. The typical viewing distance D' will have analogous dependencies as those of the viewing distance D discussed above. D' will be a function of the specific design involved.

[0039] Reference is now made to FIGS. 10 and 11 for an implementation of the screen apparatus 150 in accordance with a third embodiment of the invention. As will be appreciated by those of skill in the art of holography, modifications of the optical setup shown in FIG. 6 can be made that make it possible to record a hologram that converges (or diverges in other embodiments) light instead of collimating light. This can be accomplished, for example, by moving the lens 60 relative to the spatial filter 58 and the photosensitive material 62. Once recorded with reference and object beams as interference fringes 133, and then developed and possibly baked, as discussed above, the converging hologram (the remaining discussion will emphasize converging light instead of diverging light) could be repositioned in its original position with respect to the same or a similar reference beam for reproducing the converging object beam. In FIG. 10, such a hologram is shown as an HOE 130, which is positioned to receive image light 132 from the image engine 14. The processing or filtering (e.g., projecting by a projection or other lens, not shown) of the light 132 is generally indicated by a break in the light path and numeral 132A, as similarly discussed above. The light 132 is incident on the HOE 130 through a first surface 131 and exits the HOE 130 through a second surface 134 as converging image light 135.

[0040] Referring to FIG. 11, the screen apparatus 150 is shown, which includes the HOE 130 and a diffusive screen or diffuser 152. The screen apparatus 150 is similar to the screen apparatus 100. The HOE 130 and the diffuser 152 are layered, coated, bonded, adjacent, or suitably applied together, as similarly discussed above for the screen apparatus 100 in FIG. 7.

[0041] In operation, the incident image light 132 passes through the first surface 131 and exits the second surface 134 of the HOE 130. Upon entering the diffuser 152 (similar to the diffuser 102 described above) through a first surface 154, the light 132 is scattered as image light 158, which exits the diffuser 152 through a second surface 156. The viewer 27, suitably positioned in front of the screen apparatus 150, can see an image produced by the image light 158 at the surface 156. The position of the viewer 27 in FIG. 11 may be as shown in FIG. 9, with the light 158 exhibiting gain profile maxima directed to the viewer 27. The image light 158 in FIG. 11 is shown following paths in a substantially more downward (or centralized) direction compared to the image light 108 in FIG. 7. In FIG. 11, the direction taken by the light 158 would be expected because of the converging property of the HOE 130 compared to the collimating property of the HOE 30, and should lead to substantially more uniform image illumination as the viewer 27 moves transverse to the screen apparatus 150.

[0042] It is contemplated that the HOE **130** (or HOE **30**) could be suitably designed, using the standard techniques of holography, to direct the image light **158** (or **108**) to particular optimized (or optimal) positions or other locations of the viewer **27** in the region **115** in **FIG. 9** (or **105** in **FIG. 8**), as will be appreciated by those skilled in the art. These locations may be the best for viewing high quality images. For example, the screen apparatus could be designed to be suspended from a ceiling in a room and substantially direct its best and most uniform image downward in the room to a viewing audience below, rather than straight out along a normal direction to the screen apparatus.

[0043] The screen apparatuses **40**, **100**, and **150** described above may be advantageously employed in "folded" display apparatuses **200** and **250** shown in **FIGS. 12** and **13**, respectively, in accordance with fourth and fifth embodiments of the invention. The display apparatuses **200** and **250** may form part of a computer monitor or television display and are similar to projection systems described in prior, co-owned U.S. patent application Ser. No. 08/581,108, filed Dec. 29, 1995, by Richard M. Knox, entitled "Projecting Images" and in European Pat. app. No. 96309443.8, EPO783133A1, filed Dec. 23, 1996, by Richard M. Knox et al., entitled "Projecting Images," published Jul. 9, 1997, which are incorporated by reference herein in their entirety. The folded optical paths in the display apparatuses **200** and **250** enables the size of these image projection apparatuses to be reduced compared to other types of display apparatuses. For example, the "footprint" dimensions "L" and "L" may be made smaller by folding, which reduces the apparent projection lengths in these apparatuses.

[0044] Referring to **FIG. 12**, the display apparatus **200** includes an image engine or projector **202**, which may be similar to the image engine **14** described above. The image engine **202** may also be similar to image engines described in the aforementioned U.S. patent application Ser. No. 08/730,818. The image engine outputs image light **204** in response to input signals, for example, electronic, video, or other signals received from an antenna, cable, computer, or controller. The image light **204** reflects off a lower mirror or reflector **206** to a higher mirror or reflector **208**. The light **204** is then reflected by the upper mirror or reflector **208** and is directed to an HOE **210**. The HOE **210** may be similar to the HOEs **30**, **130**, depending on the design of the display apparatus **200**. The image light exiting the HOE **210** could, therefore, be collimated, converging, or diverging, according to the particular design, as it enters a diffusive screen or diffuser **212**, layered or coated on, bonded or adjacent to, or otherwise applied to the HOE **210**. The diffuser **212** may be similar to any one of the diffusers **42**, **102**, or **152**, according to the design. The diffuser **212** scatters the image light as light **214**, which the viewer **27** can see as forming an image at the diffuser **212** of the display apparatus **200**.

[0045] Referring to **FIG. 13**, the display apparatus **250** is shown, which includes an image engine or projector **252**, a signal splitter **254**, an input cable **256**, a sound system **258**, a screen apparatus **260**, and a back mirror or reflector **262**. The image engine **252** may be similar to image engines described above and in the aforementioned U.S. patent application Ser. No. 08/730,818. The screen apparatus **260** includes a polarizing reflector **264**, a HOE **266**, and a diffusive screen or diffuser **268**, which, depending on the specific design, may be layered, coated, bonded (e.g., with index matching adhesive), laminated (e.g., as one element), or otherwise applied together in the order shown in **FIG. 13**. The polarizing reflector **264**, the HOE **266**, and the diffuser **268** may be held together in spaced apart relation (some chromatic dispersion will occur if the HOE **266** and the diffuser **768** are spaced apart) or not in spaced apart relation (i.e., substantially with no air gaps). An example of a material that may be used for the polarizing reflector **264** is double brightness enhancement film (DBEF), also called multilayered optical film (MOF), commercially available from Minnesota Mining & Manufacturing Company, or other wide-angle polarizing reflector materials. The polarizing reflector **264** has a characteristic of preferentially reflecting light of a first linear polarization and preferentially transmitting light of a second linear polarization, orthogonal to the first polarization light. Depending on the design of the display apparatus **250**, the HOE **266** may be similar to one of the HOEs **30**, **130** described above, i.e., a collimating, converging, or diverging HOE. Likewise, depending on the design, the diffuser **268** may be any one of the diffusers **42**, **102**, or **152** described above.

[0046] The back reflector **262** includes a mirror or reflector **270** and an achromatic retarder **272** that, depending on the design, may be layered, coated, bonded (e.g., with index matching adhesive), adjacent or otherwise applied together in the order shown in **FIG. 13**. The back mirror or reflector **270** and the achromatic retarder **272** may be held together in spaced apart relation or not in spaced apart relation (i.e., substantially with no air gaps). Suitable achromatic retarders may be designed to accommodate a spaced apart arrangement, as will be appreciated by those skilled in the art.

[0047] In operating the display apparatus **250**, the image engine **252** receives an electronic signal through the input cable **256** and provides the signal to the signal splitter **254**. The signal splitter **254** divides the signal into, for example, a video signal and an audio signal, and provides these signals to the image engine **252** and the sound system **258**, respectively. The image engine **252** converts the video signal into projected image light **274**. The electronic signal received by the cable **256** may be any type of signal containing video information, such as a television signal received by an antenna or over cable lines, or a computer video signal received through a computer video cable. The audio signal and the sound system are optional.

[0048] The image light **274** may be polarized in the image engine **252** in a light source thereof (not shown) or by a polarizer (not shown) that may be employed external to the image engine **252** to polarize the image light in the first polarization discussed above. In a first instance, the image light **274** output from the image engine **252** and polarized in the first polarization direction is reflected by the polarizing reflector **264** toward the back reflector **262**. The reflected image light **274** passes through the achromatic retarder **272** a first time, is reflected by the back mirror or reflector **270**, and passes through the achromatic retarder **272** a second time directed again toward the screen apparatus **260**. The achromatic retarder **272** is designed to have an optical thickness (substantially one-quarter wave), such that the double pass of the image light **274** in the first polarization will undergo an effective half-wave polarization shift or rotation of substantially 90 degrees. Thus, the image light **274** now directed toward the screen apparatus will substantially be in the second polarization and will substantially

pass through the polarizing reflector 264 to the HOE 266. The HOE 266 collimates, converges, or diverges this light, according to the design, which is subsequently scattered by the diffuser 268 as image light 276. The viewer 27 can then observe an image produced by the image light 276 at the diffuser 268 of the screen apparatus 260, in similarity to the descriptions given above.

[0049] A method of making the screen apparatus (e.g., 100, 150 shown in **FIGS. 7 and 11**) may be set forth in accordance with a sixth embodiment of the invention. The hologram or HOE (e.g., HOEs 30, 130) for the screen apparatus may be formed by the process described above (for forming collimating, converging, or diverging HOEs), including recording in an appropriate optical setup using reference and object beams. The object beam may be produced by a collimating lens, such as the lens 60 in **FIG. 6**, or, in other embodiments, it may be recorded with the lens 60 or other suitable optics adjusted to produce a converging or diverging object beam to the photosensitive material. Once recorded, the HOE (e.g., 30, 130) is developed and may be baked, as previously described.

[0050] The method also includes forming a diffuser (e.g., 102, 152) by mixing two or more immiscible or particulate materials (e.g., polymers) having different indices of refraction with one of the materials having physical properties sufficient for forming light scatterers within a matrix of the other materials. The diffuser may otherwise be provided as a commercially available diffuser, as discussed above. The HOE (e.g., 30, 130) is then suitably mounted to be generally parallel to the diffuser (e.g., 102, 152) for receiving the incoming light (e.g., 32, 132 shown in **FIGS. 7 and 11**). The mounting process may include lamination as a single element (e.g., with an index matching adhesive or material between the HOE and the diffuser), layering or coating, adjacent placement, or otherwise suitably applying the HOE and the diffuser together. The method contemplates the placement of the HOE (30, 130) and the corresponding diffuser (102, 152) in spaced apart relation with the air gap (not shown) therebetween or not.

[0051] In all the embodiments of the invention, as previously described, diffusive viewing screens or beaded screens are included in the screen apparatus. Both types of screens are generically referred to herein as diffusers. The beaded screens capture stray imaging light elements, have a limited acceptance angle, and the stray light is absorbed in a black matrix. The diffusive screen, on the other hand, scatters the stray light so that it may be somewhat homogeneous or uniform in intensity across the viewing screen. The type of diffusive screens include bulk diffusive screens. In other embodiments of the invention, surface diffusers, for example, ground glass and the like, could also be used instead of diffusive screens or beaded screens.

[0052] The screen apparatus embodiments of the invention should be designed so that the particular order, for example, the first order of the diffracted light would be the collimated light used for imaging. This would include approximately 95-96% (could be up to or greater than 99%, or much less) of the light diffracted by the holographic optical element into the first order, depending on the type of hologram and/or the cost of making the hologram. The other approximately 4-5% of the light is diffracted into other orders, including the zero order, although if the HOE 30 is a volume hologram, there is (or substantially is) no other relevant order besides the zero order. It is contemplated that the HOE 30, 130 may instead be a reflection-type HOE rather than a transmissive-type HOE, which could be used to provide collimated light in reflection. In applications that require little or no chromatic dispersion, a reflection-type HOE may be desirable because, in certain embodiments, the reflection-type HOE may exhibit substantially little or no chromatic dispersion. The recording and formation of such a reflection-type HOE will be understood and appreciated by those skilled in the art. Once a master reflection-type HOE is made, it may be replicated using standard processes, such as embossing for surface kineform or surface relief HOEs, as can be provided by Polaroid or by using equipment purchased from DuPont. The screen apparatus embodiments should also be designed to prevent a hot spot from occurring on the screen, as discussed above. This could potentially lead to contrast problems otherwise, for example, screen corners darker than in the screen center, or having a peak of the imaging light intensity occur off-access as viewed on the screen apparatus. Appropriate design of the HOE 30, 130 and the corresponding diffuser 42, 102, 152 in combination should assure more uniform illumination and avoid a hot spot, as the image light can be turned (e.g., collimated, converged or diverged) to avoid or substantially reduce oblique screen illumination.

[0053] The particular embodiments disclosed above are illustrative only, as the invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. For example, the HOEs described herein could instead be reflection-type HOEs, as discussed above, suitably designed to work in analogous fashion with diffusers, but in reflection-based screen apparatuses or displays. Moreover, image generation devices of the type (e.g., that include one or more cathode ray tubes or CRTs for forming an image) described in U.S. Pat. No. 5,557,343, issued to Yamagishi, entitled "Optical System Including A Reflecting Polarizer For A Rear Projection Picture Display Apparatus," incorporated by reference herein in its entirety, could be used as the image engine 14 and are intended to be included within the scope of the present invention. Other types of image generation devices known in the art could be used as the image engine 14 and are intended to be included within the scope of the present invention, as well. Furthermore, no limitations are intended to the details of construction or design shown herein, other than as described in the claims below. It is therefore evident that the particular embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of the invention. Accordingly, the protection sought herein is as set forth in the claims below.

What is claimed is:

1. An screen apparatus comprising:

a holographic optical element adapted to receive image light and to redirect the image light; and

a diffuser adapted to receive the redirected image light from the holographic optical element and to scatter the redirected image light.

2. The screen apparatus of claim 1, wherein the holographic optical element and the diffuser are adapted to provide a substantially uniformly illuminated viewing region.

3. The screen apparatus of claim 2, wherein the viewing region comprises an optimized viewing position.

4. The screen apparatus of claim 1, wherein the holographic optical element is adapted to substantially collimate the image light.

5. The screen apparatus of claim 1, wherein the holographic optical element is adapted to substantially converge the image light.

6. The screen apparatus of claim 1, wherein the diffuser comprises two or more immiscible materials.

7. The screen apparatus of claim 1, wherein the holographic optical element and the diffuser are adjacent with substantially no air gap therebetween.

8. The screen apparatus of claim 1, further comprising index matching material between the holographic optical element and the diffuser.

9. The screen apparatus of claim 1, wherein the holographic optical element and the diffuser are adapted to provide gain profiles of image light substantially directed toward a viewer.

10. The screen apparatus of claim 1, wherein the diffuser focuses the redirected image light as it passes through the diffuser.

11. The screen apparatus of claim 1, wherein the holographic optical element and the diffuser comprise an air gap therebetween.

12. The screen apparatus of claim 1, wherein the holographic optical element and the diffuser are comprised in part of a computer monitor.

13. The screen apparatus of claim 1, wherein the image light comprises substantially white light.

14. The screen apparatus of claim 1, wherein the holographic optical element and the diffuser comprise a flexible combination.

15. The screen apparatus of claim 1, wherein the holographic optical element and the diffuser comprise a laminated element.

16. The screen apparatus of claim 1, wherein the holographic optical element comprises a transmission-type holographic optical element.

17. The screen apparatus of claim 1, wherein the holographic optical element comprises a reflection-type holographic optical element.

18. The screen apparatus of claim 1, wherein the holographic optical element comprises a photopolymer material.

19. The screen apparatus of claim 1, wherein the holographic optical element records an interference pattern for redirecting the image light.

20. The screen apparatus of claim 1, wherein the holographic optical element and the diffuser comprise a gap therebetween that is substantially minimized for reducing effects of chromatic dispersion.

21. The screen apparatus of claim 1, wherein the holographic optical element and the diffuser are adapted to provide the redirected image light predominantly to a particular viewing position.

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